

FURANIC COMPOUNDS IN INSULATING FLUIDS



The Nature of Cellulose Insulation

Paper insulation used in electrical equipment is a manufactured cellulose based product. Cellulose is a naturally occurring polymeric material that nature builds by linking together D-Glucopyranose monomers.

The average number of monomers in the cellulose chains is called the degree of polymerization, DP, and is designated n , as shown in Figure 1.

New Kraft paper, named for the German word for strong, has a DP in the range of 1000-1300.

The physical strength of paper insulation is related to the average DP and the interaction between adjacent chains.

As the paper ages, linkages between adjacent monomers are broken and the DP decreases. "Middle Aged" paper has a DP of about 500. Paper with a DP of less than 250 is in its "Old Age" and has very little

remaining life as solid insulation material. Cellulose with a DP of 150 or below is basically a powder without significant mechanical strength.

Determining the Condition of Insulation

The DP of paper can be determined in the laboratory utilizing ASTM method D-4243.

Acquisition of a paper sample is an invasive and expensive procedure that requires taking the unit off line.

A non-invasive alternative has been developed recently. The procedure is based on the determination of oil soluble cellulose decomposition products. These compounds, substituted furans, are shown in Figure 2.

Weidmann-ACTI can isolate these compounds from an oil sample and analyze them with High Performance Liquid Chromatography, HPLC. Detection limits are at the 10 PPB concentration level. The most significant compound is 2-Furfuraldehyde and concentrations of this compound have been correlated with DP.

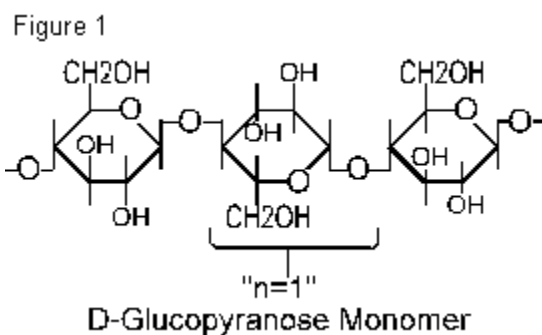
Chendong has developed an empirical correlation between the concentration of 2-Furfuraldehyde and the DP.

$$\text{Log [Fur]} = 1.51 - 0.0035 \text{ DP}$$

where [Fur] = conc. of 2-Furfuraldehyde in PPM.

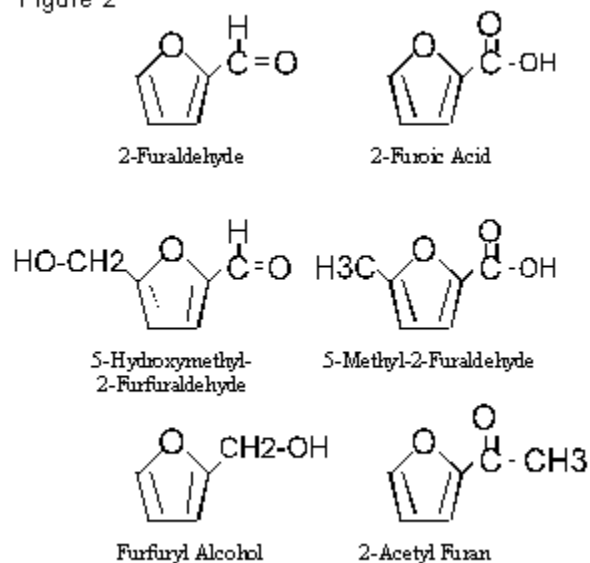
This equation, though not exact, allows one to estimate the DP of cellulose insulation. Knowing the DP value, one can estimate the remaining insulation life of a transformer.

The Chemical Structures of Cellulose Insulation and Degradation Products



A Portion of the Insulation Molecule

Figure 2



Cellulose Decomposition Compounds Found in Oil

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